[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. VII.—*The Diabases and Associated Rocks of the Howqua River near Mansfield, with reference to the Heathcotian Problem in Victoria.*

By E. O. TEALE, D.Sc., F.G.S.

With an account of the Petrography of the Diabases by
Prof. E. W. Skeats.

(With Plate IV., 4 Text Figures and Map).

[Read July 10th, 1919].

Contents.

1. Introduction.
2. Position and Access to the Howqua Region.
3. Physiographical Features.
4. General Geology.
5. Lower Palaeozoic Rocks (Heathcotian to Silurian).
    A. Diabases:—
        (a) Normal Diabase.
        (b) Soda Rich Diabase.
        (c) Platy Diabase.
    B. Tuffs and Agglomerates.
    C. Alteration features of the Diabase:—
        (a) Red Jasper.
        (b) Siliceous—carbonate rocks.
        (c) Talc rocks.
        (d) Serpentine and Chrysotile.
        (e) Mineralization of the Diabase—Auriferous sulphides, etc
    D. The Sediments:—
        (a) Their Lithological features.
        (b) Apparent structural relationships.
        (c) Phosphatic Deposits.
    E. Concerning the Age of the Diabase and Cherts—a comparative review.
6. The Upper Palaeozoic Rocks.
    A. Devonian:—
        (a) Dacite-porphyry.
        (b) Grano-diorite.
        (c) Diorite.
    B. Lower Carboniferous:—
        (a) Basal conglomerates.
        (b) Rhyolite.
        (c) Conglomerate.
        (d) Sandstones.
        (e) Purple shales.
7. Summary and conclusions.

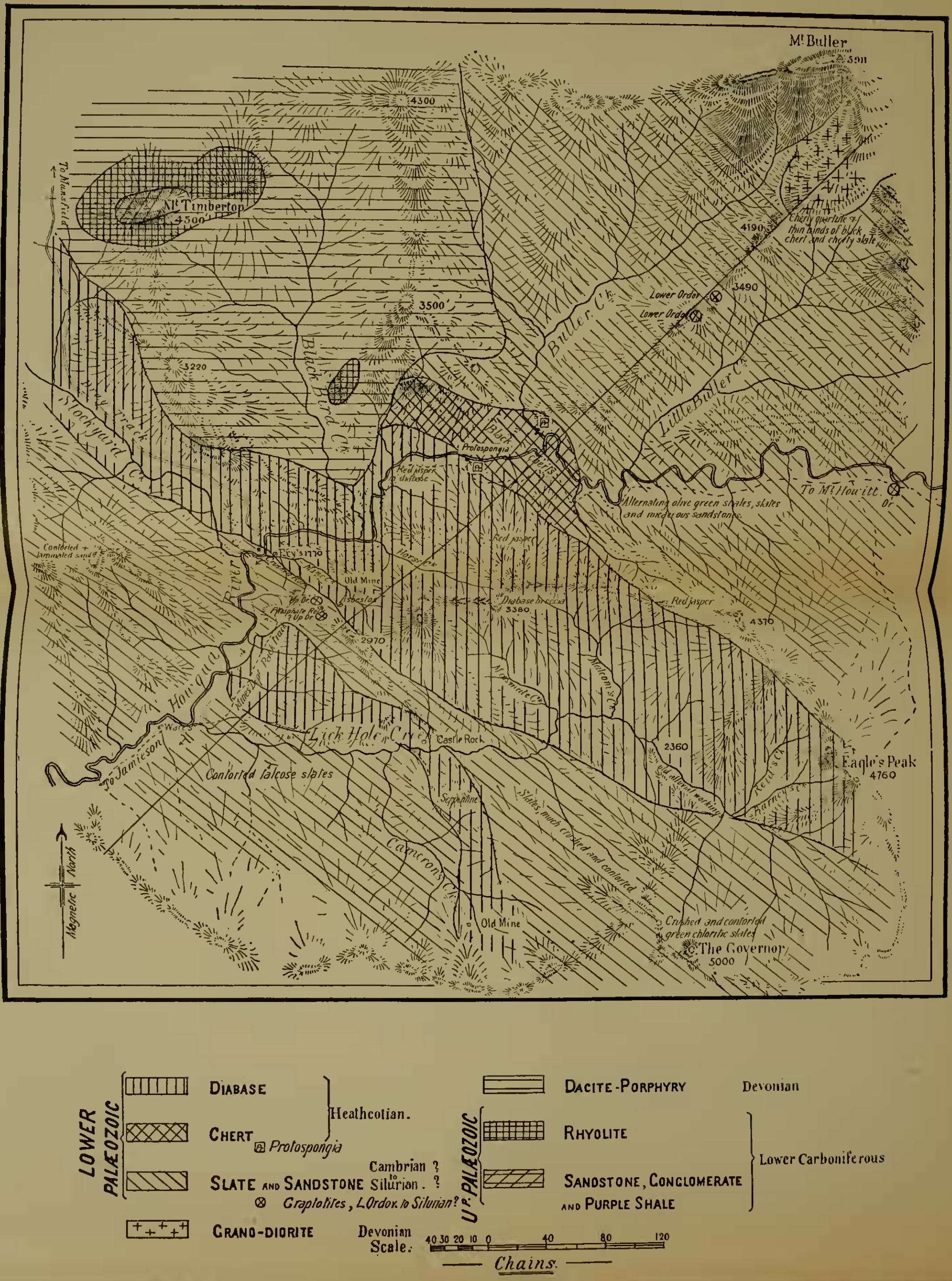
1.—Introduction.

The existence of serpentine and associated basic igneous rocks in the Howqua River to the south-west of Mount Buller was first referred to by Mr. A. M. Howitt,[1] in 1907, in the Records of the Geological Survey in a short note with an accompanying sketch map. Mr. Howitt's visit was an extremely short one, allowing only about a day in the field, and his main object was to report on the supposed occurrence of phosphate of alumina similar to that found near Mansfield. He, however, was able at the same time to note the outcrop of a considerable extent of basic igneous rocks and black cherts. The latter he regarded as probably Heathcotian, on account of their resemblance to similar cherts at Heathcote, which had then been recently placed in that group by Professor Gregory.[2] The igneous rocks he described as amphibolites, which he regarded as intrusive into the Lower Palaeozoic and of Devonian age. He also obtained a graptolite from the Palaeozoic slates which the late Dr. T. S. Hall referred to as a Monograptus,[3] thus indicating Silurian strata. The amount of information collected by Mr. Howitt in a short time, and in such rough and mountainous country, is remarkable. The writer having spent considerable time in the Mount Wellington district in Gippsland, examining the area where serpentine and associated Upper Cambrian limestones occur, came to the conclusion that an important axial line existed in the Wellington region. The extension of the line to the north passes through inliers of closely similar rocks on the Howqua, and at Dookie.

When, therefore, Professor Skeats suggested that I should take up the study of the Howqua region, with the assistance of a Government Research Scholarship, I was very glad to avail myself of the opportunity. I would like at this stage to specially express my indebtedness to Professor Skeats for his interest and assistance in this work. He not only visited the out of the way region on the Howqua, spending about a week in the field with me, but very kindly conducted me over the Lancefield and Heathcote areas, which may be looked upon as the type occurrence of the much debated Heathcotian series.

This work has been invaluable for comparative purposes in dealing with the Howqua region. In the Geological Laboratory of the University, too, I have had advantage of full access to the numerous slides and hand specimens from these regions. It is very helpful

GEOLOGICAL SKETCH MAP, HOWQUA HILLS
SOUTH EAST OF MANSFIELD

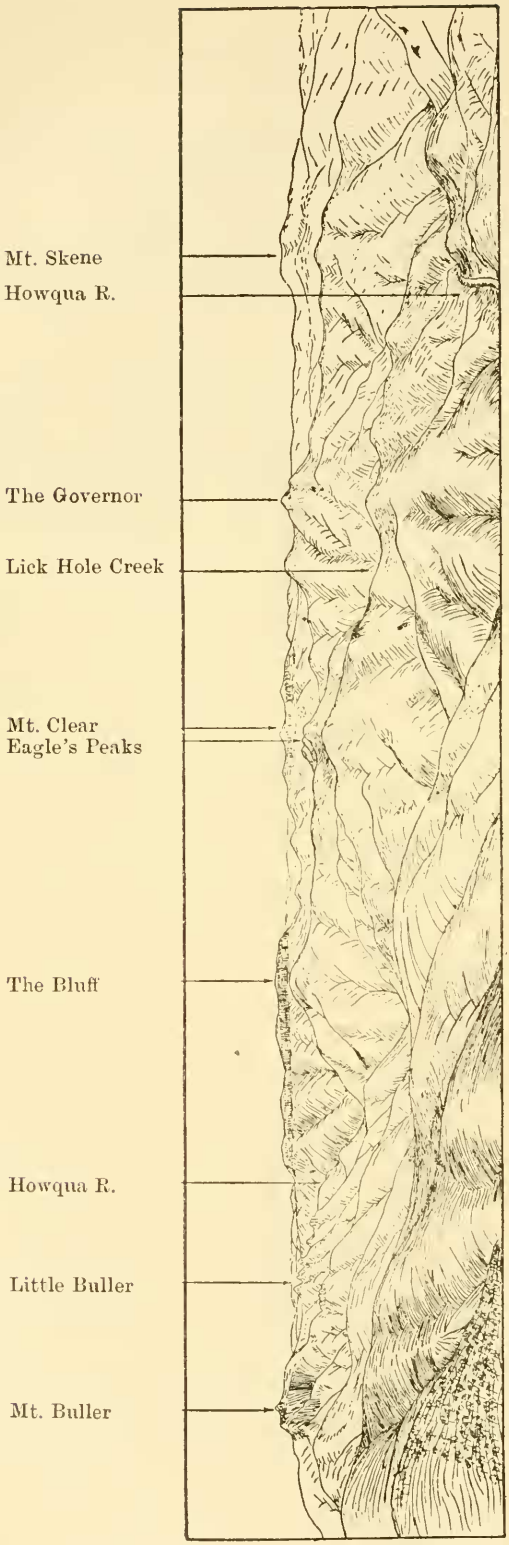


therefore to be able to treat the new area in a comparative manner with the better known regions. While there are certain gaps and differences in the Howqua region, as compared with Lancefield, Heathcote and the Dolodrook, near Mount Wellington, many of the comparisons are strikingly similar. It is possible to match many of the special rocks of Heathcote so closely that were the specimens not labelled, it would be impossible to distinguish them from each other.

The problems of the Heathcotian series and the controversial questions wherein Professor Skeats, Mr. E. J. Dunn, Professor J. W. Gregory, and the late Dr. A. W. Howitt either agreed with or differed from each other, have been ably set out by Professor Skeats ([4] and [5]), so that it will only be necessary to enumerate here in due place those special aspects which call for consideration in conjunction with the Howqua area. Many important features in the Lower Palaeozoic history and structure in Victoria are dependent on the elucidation and interpretation of the origin, age and relationships of the various rocks in the scattered inliers of diabases and cherts, now generally included in the Heathcotian series. Regarding this series, field work proves that the Heathcotian conformably underlies graptolite bearing Lower Ordovician rocks, and on field evidence therefore it might be Lower Ordovician or Cambrian. It is on the reconsideration of the Dinesus material on which the original claim for a Cambrian age, subsequently abandoned, is now reasserted, and appears to be established, that it becomes necessary to include the lowest beds generally known as Heathcotian in the Cambrian.

2.—General Location of the Howqua Region.

The area under consideration lies to the south-east of Mansfield just within the rough mountainous region of the central highlands of Victoria. It is distant by road from Mansfield about 22 miles. For 12 miles, as far as Merrijig, on the Delatite River, the road is good, thence the route follows an old track little used, and in a very poor state of repair. By this a steep ascent is made over the shoulder of a ridge overlooked by Mount Timbertop, to drop down into the deep mountainous valley of the Howqua, a striking contrast in its rugged and almost uninhabited character from the open park-like grazing and farming district of Mansfield.



Central Victorian Highlands.
Howqua Region.

Sketch from Mt Timberlop from east to south showing stage of dissection and remnants of overmantle of horizontal or relatively flat lying rocks.

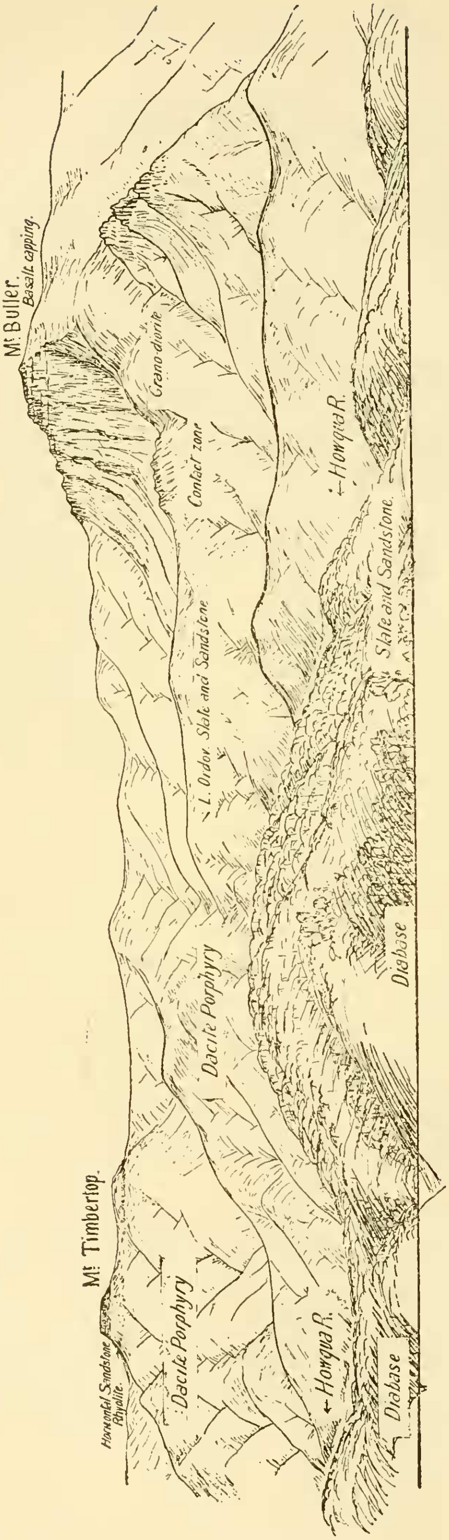
Fig. 1.

3.—Physiographical Features.

Physiographically, the Howqua area is in an interesting position. It lies near the northern edge of the great central highland belt of Victoria, close to the wide and striking sunkland of the Mansfield district, the development which has had such a remarkable and interesting effect on the history of the river system of this region, the details of which have been ably discussed by Fenner.[6]

Standing on the commanding viewpoint of Mount Timbertop, at about 4500 feet, the general survey of the physiography is particularly interesting, and is scenically both grand and varied. (See Fig. 1.) To the south and east especially the view is most imposing, looking out over the deep Howqua Valley, across the fretted and dissected northern portion of the central plateau, the highest portions of which rise to close on 6000 feet. Mount Buller, the nearest, about four miles to the east, at 5911 feet, present a precipitous front to the west, and forms, with its basalt capped summit, a striking remnant of the old plateau, with the valleys of the Delatite and the Howqua on either side 4000 feet deep. At Timbertop the observer is standing in a small outlier of the flat lying Upper Palaeozoic strata, with the frequently associated rhyolite at the base. To the east and south-east he looks over a vast extent of deeply dissected country, from which the great overmantel of hard, almost horizontal, rocks has been removed, exposing the underlying highly inclined Lower Palaeozoic rocks, chiefly slate and sandstone. The central watershed of the State, known as the Main Divide, lies about 20 to 30 miles distant in this direction, and presents a precipitous and ledged front, due to the same more or less horizontal strata as those on Timbertop. Mounts Magdala, Clear and Macdonald, are the most noteworthy points, while the Bluff of similar structure, distant about ten miles, adds to the rugged character of the scene. Should these mountains be snow-covered, as they frequently are in the winter, the ledged character is generally emphasised.

The whole view in this direction, and as far round as Mount Torbreck to the south-west, about 25 miles away, overlooks the basin of the Upper Goulburn and its tributaries. It may be described as a mountainous region of high relief in an advanced stage of dissection. The original plateau character has been almost obliterated, only restricted ridges within the basin, which rise to about 5000 feet, remain to indicate its former features. The old



SKETCH FROM EAGLE'S PEAK LOOKING NORTH TO NORTH WEST,
HOWQUA VALLEY.

Fig. 2.

plateau is best preserved round the margin along the main Divide. These relatively flat, elevated areas at 5000 feet and over are locally known as snow-plain country. They form summer feeding grounds for cattle during a few months of the year. The Howqua valley is one of the main cattle routes to these summer grazing areas from the low country. A bridle track follows its course towards the headwaters, where it rises to the open grassy plain near Mount Howitt. The economic value of the region does not lie in its possibilities from a point of view of settlement. Both from an agricultural and pastoral point of view its capabilities are almost negligible, but it forms an important collecting ground and store-house for water supply. It is here that the Goulburn gathers its waters, the value of which for irrigating its fertile alluvial plains is now being widely recognised.

4.—General Geology.

The area specially considered from a geological point of view lies on either side of the Howqua River, with Mount Buller in the north-eastern corner, and comprises about 60 square miles of country. The diabases and associated rocks, which are specially referred to in this paper, cross the tract from north-west to south-east, which is the general trend or grain of the structure as a whole.

One great handicap to investigation in this region apart from its uninhabited and mountainous character was the absence of any map suitable for the work in hand. A surveyed traverse of the Howqua River was kindly supplied by the Lands Department, and with this as a basis, the rest of the topography was sketched in by means of prismatic compass methods, which was the best that could be done under the conditions.

The rocks of this region, with the exception of a small outlier of Kainozoic basalt on the summit of Mount Buller referred to by Fenner[7] are entirely Palaeozoic, but they range in age, probably from Cambrian to Lower Carboniferous, and include both sedimentary and igneous rocks. They may be conveniently considered first in chronological order, starting with the oldest. (See Fig. 2.)

5.—Lower Palæozoic.

This includes rocks which range from Cambrian to Silurian, covering more than three-fourths of the area under consideration, but the exact mapping of the boundaries is rendered very difficult on acount of the intense folding and crushing to which the series as a whole has been subjected, together with the sporadic and apparently erratic distribution of the fossils, which are mainly graptolites in poor state of preservation, and *Protospongia.* The only fossils obtained from the Cambrian in this region are *Protospongia*, and possibly radiolaria from black cherts similar to those of Heathcote.

Cambrian (Heathcotian Series).

The rocks of this series fall into two groups :—

1. Basic igneous rocks (diabases in part), and associated tuffs, with their alteration products.

2. Protospongia cherts.

A.—The Diabases.

1. The basic rocks referred to here form an important central occurrence in the area under consideration. There are two belts, more or less parallel, but of unequal size, both, however, with a general north-west to south-east direction. The largest and longest starts outside of the area at least a couple of miles to the north-west, and passes out of the map in the south-east, where its extension has not been examined. Its greatest width is about $1\frac{3}{4}$ miles; the outline is somewhat irregular along portion of its north-eastern side, where it comes in contact with the dacite porphyry, but otherwise the junction and trend conform closely with the general strike of the enclosing sediments.

The smaller belt is shorter and narrower, and ends bluntly on the Howqua, as shown on the map. It would appear to diverge somewhat in direction from the larger belt towards the south in the Cameron's Creek area, which has, however, been only imperfectly traced.

In general, the boundary of these rocks is readily traced in the field, on account of the sharp soil change from the rich dark red of the diabase to the poorer slaty soil of the surrounding rocks. The open, park-like and grassy slopes of the diabase, too, are often in striking contrast to the closer forest with scrub undergrowth of the sedimentary rocks, so that from suitable vantage points the general bearing and limits of the two formations can be distinctly observed from a considerable distance. This is quite analogous to the "clear country," of the serpentine area in the Dolodrook.

The *Protospongia* cherts bound the diabase along the eastern side of the main mass, forming a well-defined belt, about half a mile wide. Numerous specimens, showing the characteristic cruciform spicular arrangement of *Protospongia*, were found in the field in these cherts, and a microscopic section, No. 78, from this belt of cherts, displays well the abundance of the sponge spicules embedded in a dark, largely chalcedonic ground mass. (See Microphoto Plate I., Fig. 3.)

In the Heathcote area Dr. Howitt held that the silicification of corresponding rocks was a metamorphic effect, due to the intrusion of the diabase, an interpretation which is dissented from by Professor Skeats, who shows good reasons for regarding them in part as altered submarine tuffs, silicified by metasomatic action, the adjacent igneous rock being considered as mainly contemporaneous lava flows.

The features are closely analogous here, where the *Protospongia* cherts are found. These fossiliferous cherts have not been recognised along the western boundary nor along the contact of the smaller diabase occurrence. In general, the western junction of the main mass is marked by much crushing and shearing, with other accompanying alterations in both the igneous and the sedimentary, but nothing attributable to contact alteration has been noted. Shistose talc rock is abundant in the valley of the Stockyard Creek, and elsewhere, close to the junction. An important section is exposed in the bed of the Howqua at the foot bridge, where the old dray track from Merrijig ends. The diabase crosses the river in a north-west direction, just above the bridge, forming a bar, and an interesting series of intensely crushed rocks of somewhat varied character can be traced more or less continuously from within a few yards of the contact down stream for about three chains. A short break of about two chains intervenes, where the exposure is masked, and then crushed black slate follows, forming a conspicuous cliff, at the bend of the river. The crush zone here is at least five to six chains wide. A noteworthy feature is that the rock adjoining the diabase shows not the slightest contact alteration at a distance of less than a yard from the junction. Intensely crushed and contorted rocks are the general rule along the contact. This feature, together with lithological and fossil differences of this zone compared with that in the eastern edge are worthy of note, and will call for further comment later, when dealing with the sedimentary rocks and general structural considerations.

(*a*). *Normal Diabase.*

The diabasic rocks show some variation in character from a somewhat doleritic type to that of a dense basalt, the latter being the dominant type. The dense forms are almost identical in features with those of Heathcote.

Though the sections at the Howqua do not show so clearly the same interbedded succession, the character and occurrence of the diabase, and that of the associated cherts are so similar that the assumption is reasonable that here, too, they represent similar submarine lavas, and tuffs, or interbedded cherts.

CHEMICAL ANALYSES OF DIABASES
By E. O. Teale

	Howqua		Heathcote
	No. 15	No. 25	No. 630
SiO_2	46.44	58.17	55.77
Al_2O_3	15.71	13.15	11.23
Fe_2O_3	.53	3.18	1.82
FeO	11.21	8.61	10.11
MgO	8.61	0.91*	7.94
CaO	12.3	6.7	4.64
Na_2O	2.5	7.00	4.91
K_2O	.21	0.41	.73
H_2O+	.21	0.33	.55
H_2O-	2.54	1.34	1.91
TiO_2		0.8	0.22
	100.46	100.61	99.80

* Note low MgO content

NO. 25.—SODA, RICH TYPE.

Mineral.	Norm. %	Group.	%
Quartz	.72	Q.	Salic. 65.17
Orthoclase	2.22	F. 64.45	
Albite	59.21		
Anorthite	3.07		
		L.	
Diopside	28.0	P. 31.56	Femic 4.55
Hypersthene	3.56		
Magnetite	4.4	M. 4.55	
Ilmenite	.15		

Class $\frac{\text{Sal.}}{\text{Fem.}} = \frac{64.45}{31.56} < \frac{7}{1} > \frac{5}{3}$ = Class 2. Dosalane.

Order $\frac{\text{Q.}}{\text{Fem.}} = \frac{.72}{64.45} < \frac{1}{7}$ = Order 5. Germanare.

Rang. $\frac{K_2O + Na_2O}{CaO} = \frac{117}{120} < \frac{5}{3} > \frac{3}{5}$ = Rang. = Alkali Calcic. Ilmenose.

Sub-Rang. = $\frac{K_2O}{Na_2O} = \frac{4}{113} < \frac{1}{7} >$ = Sub-Rang. = Persodic. Beerbachose.

(*b*) *The petrography of the diabases, including soda-rich types.*

(By Professor E. W. Skeats.)

Reference to the chemical analyses shows that diabases of fairly normal composition are present. The analysis of No. 15 shows that as regards the alkali content, it is normal, but has a high content of the alkaline earths, especially of lime. No. 25, however, on analysis proves to have a very high soda content, and is unusually low in lime. It evidently has suffered albitization, and shows that the spilite type of magma is represented among the Howqua diabases, and the analysis of a diabase from Heathcote is also relatively rich in soda.

The petrographic descriptions which follow show that albitization, silicification, chloritization, the production of secondary hornblendes from augites, the formation of carbonates, and the development of the mineral lawsonite, are features of fairly common occurrence among the Howqua diabases, which in hand specimen, may not appear to be specially altered.

The term diabase, used to describe these rocks, has been found useful to retain, although it is now clear from their field relations and principal petrographic characters that they are mainly submarine lava flows and ashes.

No. 11.—Diabase from the ridge between Howqua River and Lick Hole Creek. The rock consists of pale-coloured augite to the intent of about 3-5th, and a very kaolinized felspar to the extent of about 2-5th of its volume. The augite is diallagic in part. Both augite and felspar seem to have started crystallizing simultaneously, as each in places is porphyritic, and in other places is moulded on the other. The felspar is too cloudy for specific determination, a little ilmenite, altered to leucoxene and of chlorite after augite, is also present. Some secondary clear to cloudy chalcedony is also present, partly replacing felspar.

MARINE BIOLOGICAL LABORATORY
WOODS HOLE, MASS.
LIBRARY

No. 12.—Locality east of No. 11, but on the same ridge. The rock is moderately coarse-grained; about two-thirds consists of felspar, mostly as relatively large rectangular phenocrysts. with a small amount of later micro-spherulitic felspars moulded on them. The phenocrysts are mainly albite, or Ab_{90} An_{10}, having a refractive index as low as the mounting balsam, which is less than 1·53. Some felspars are untwinned, possibly 010 sections, with extinction angles, ranging from 3°-19°. Others show carlsbad or albite twinning, or both. Symmetrical extinction angles of 15°-18° occur on the albite lamellae. Some of the felspar is saussuritized to granules of epidote and zoisite. The bulk of the felspar slightly preceded the augite in crystallizing, but in one place augite and felspar are in micrographic intergrowth. A fair quantity of ilmenite occurs in elongated crystals, and is more or less altered to leucoxene. Clusters of radiating, brown, green or bright red micaceous products occur. In one place crystals of a secondary red micaceous mineral product radiate from the ilmenite at right angles and granular epidote is also associated with it. A little pleochroic aegirine-augite, with extinction angle of 29°, is also present. The rock may be described as an albite diabase.

No. 15.—Compact diabase, from Four Mile Creek (analysed). (See Plate I., Fig. 2.) There is very little felspar present, and this consists of lath-shaped crystals and larger areas now altered to zoisite and minute secondary mica flakes. The rock consists mainly of granular augite, with some areas of chlorite, a fair quantity of ilmenite altered to leucoxene, and some granular pale brown sphene.

This mineralogical content is in agreement with the high lime and magnesia, and low alkali content of the analysis.

No. 16.—Spotted diabase from Four Mile Creek. In the hand specimen light circular spots are noticeable, but are much less prominent under the microscope. However, slightly lighter areas can be seen, and appear to be due to the relative crowding of minute more or less altered lath-shaped felspars, while a relatively smaller amount of augite and chlorite occur in these areas than in the rest of the rock. One large phenocryst of plagioclase now consisting mainly of chlorite and secondary felspar, was noticed, and minute granular oxide of iron, with a little carbonate, occurs. The augite is mostly granular in habit, with undulose extinction.

No. 17.—Compact diabase from smaller diabase outcrop on the track to Ware's, and south of Fry's.

In this rock much recrystallisation under pressure has occurred. Most of the augite has recrystallized as fibrous secondary hornblende, with light to dark green pleochroism, and extinction angles ranging from 11° to 21°. The felspar has recrystallized to water clear secondary felspar, with enclosures of secondary hornblende needles. Ilmenite in large skeleton rhombohedra altered to leucoxene, is fairly abundant. Some interstitial secondary calcite is present. The extensive recrystallization of the rock is no doubt referable to its occurrence in a crushed zone, south of Fry's, and it resembles some of the recrystallized diabases of Heathcote and Mt. William, near Lancefield, but is hardly so altered as the epidiorites of Ceres, near Geelong, since some relic structures in the form of original augite and felspar are still noticeable.

No. 18.—Diabase, south-east of No. 17.

A diabase which has suffered fairly complete recrystallization to fibrous hornblende, and secondary water clear felspar. In the process a considerable amount of granular and dusty magnetite has separated out.

No. 22.—From main diabase mass, Lick Hole Creek, and east of isolated crushed diabase mass. A relatively coarse-grained type with no signs of recrystallization under pressure. Coarse plates of augite and cloudy felspar form the bulk of the rock, with chlorite and clear felspar as secondary products.

No. 25.—Soda rich diabase (analysed), Lick Hole Creek, one mile north of the Governor, and near the south-east end of the main diabase mass. (Micro. Photo., Plate I., Fig. 1.)

About 2-3rds of the rock consists of felspar in large and small prismatic, quadrate or irregular crystals. Simply twinned and untwinned crystals are abundant, and some show lamellar twinning. The low refractive index, positive sign, and biaxial figure show that albite or albite-oligoclase predominates. All the felspars are clear, and some contain secondary hornblende and chlorite, suggesting recrystallization. Some original augite remains, but much is altered, either to normal hornblende or green pleochroic fibrous actinolite. Sphene, epidote and zoisite occur in granules. Brown clusters of radiating biotite crystals occur, and some calcite, a little quartz, and a few elongated prisms of apatite are present. The high albite content of the rock is confirmed by the chemical analysis, but it is difficult to reconcile the relative abundance of ferro-magnesian minerals with the strikingly low magnesia content recorded in the analysis.

No. 40.—Diabase on spur, east of Blackbird Creek, north of Howqua River, and about one mile E.N.E. of Fry's. A rock type in which augite and its alteration product chlorite predominate and felspar is in subordinate amount. Some of the felspar probably preceded the augite in crystallizing, and recrystallization of felspar, with resulting inclusion of chlorite has probably occurred. Ilmenite granules have changed to sphene.

No. 41.—Diabase from Castle Rock, Lick Hole Creek. A diabase which has suffered much secondary albitization. Augite is altered to pale and to brown secondary hornblende. The original felspar is now quite cloudy, chlorite is developed, and an irregular vein of secondary albite or albite-oligoclase traverses the section. It looks like quartz in ordinary light, but is identified by the presence of some lamellar twinning, by its refractive index, which is less than 1·53 and by biaxial figures with positive signs. Ilmenite, more or less altered to sphene, and hematite, are present. The albite in the vein occurs in clear interlocking crystals, associated with calcite, and with fibrous secondary hornblende.

No. 42.—Diabase, near No. 41. A rock similar to No. 41, but with only a minute vein of secondary albite, traversing the section.

No. 72.—Silicified fine-grained diabase from Four Mile Creek, near the massive black bedded cherts at the north-east margin of the main diabase mass. In the fine-grained diabase area a little augite remains, but most of it is altered to chlorite and secondary hornblende. Lath-shaped, water clear felspars, with chlorite inclusions occur. Sporadic secondary quartz occurs in granules in the mass of the diabase, but in over half the section the diabase has been completely replaced by a radial and granular aggregate of chalcedonic silica, with some coarser grained quartz crystals. The rock has a spotted appearance, due to greater concentration of felspar laths in roughly circular areas.

No. 73.—Diabase from Four Mile Creek, near to 72. This rock is rather coarse grained. Brown unaltered augite and large lath-shaped albite or albite-oligoclase, many with chlorite inclusions, form the bulk of the rock. Opaque iron oxide is fairly abundant, and large areas of chlorite, apparently not derived from augite, occur.

No. 107.—Diabase from spurs south of Barney Creek, at south-east end of main diabase mass. The rock may be described in its present condition as a micrographic quartz-diabase. Some original augite remains, but most of it has changed to secondary hornblende. Chlorite is abundant, ilmenite altered to sphene is prominent, porphyritic crystals of albite or albite-oligoclase, one or two prismatic crystals of apatite, and some relatively large irregular quartz crystals occur. The background is a beautiful micrographic intergrowth of quartz and albite, the latter showing lamellar twinning in places, and a refractive index lower than quartz. The micrographic background and the larger quartzes both appear to be of secondary origin.

No. 108.—Diabase from spur south of Barney's Creek, Upper Lick Hole Creek Valley, at south-east end of main diabase mass. A diabase of moderate grain size, in which very complete secondary alterations of the original minerals, augite, felspar and ilmenite have occurred. A little original grey brown augite remains, but most of it has been changed to secondary hornblende, some of it prismatic to tabular, some to fibrous actinolite, some to vivid green chlorite in clusters of radiating fibres. Quartz occurs in scattered granules, and in micrographic intergrowth with augite and with chlorite. This quartz may be primary or secondary. Much secondary quartz occurs, more or less completely replacing the lath-shaped felspars which, however, still show the outlines of the crystals and the positions of the twin lamellae in a remarkable way. An irregular vein, about $\frac{1}{8}$ inch wide, traverses the rock, and consists partly of quartz, but mainly of colourless to cloudy prismatic and radiating crystals of lawsonite, a hydrated silicate of lime and almuminium. The mineral is recognised by its positive sign, and biaxial character, its high refraction and polarization colours up to second order, whereas the quartz shows low neutral tints. The lawsonite is a secondary mineral derived mainly from the alteration of the felspar, but in places is seen to develop from altering ferromagnesian minerals in the mass of the rock. Ilmenite is partially altered to leucoxene, and a little secondary calcite and epidote are also present. No secondary albite was recognised in the rock, and the original felspars are so altered either by becoming cloudy, through incipient saussuritization or replaced by quartz, that their original character is unrecognizable.

No. 109.—Diabase from same locality as No. 108. A moderately coarse grained rock which is free from quartz, but otherwise has suffered much the same changes as has No. 108. The large platy albite or albite-oligoclase felspars have chlorite inclusions. Some augite has developed a diallagic structure, and there is a considerable development of secondary lawsonite, principally in clear to cloudy minute radiating crystals.

No. 118.—Diabase from Upper Lick Hole Creek, one and a-half miles N.N.W. of The Governor.

A diabase in which albitization is a marked feature, resulting in the formation of clear secondary platy crystals, and raditaing lath-shaped crystals. The augite is mainly converted to secondary hornblende, some of which is normal, while some is fibrous, pleochroic actinolite. A good deal of calcite occurs, but neither quartz nor lawsonite have been recognised.

No. 119.—Diabase from same locality as No. 118. A coarse-grained type, with cloudy felspars, pale augite, partly replaced by hornblende, and a little quartz.

No. 121.—Diabase from Lick Hole Creek, quarter mile west of No. 118. A rock similar to No. 119, but with an abundance of large opaque crystals of magnetite or ilmenite.

No. 122.—Diabase from same locality as No. 121. A rock almost identical in characters with No. 118.

(c) *Platy and Splintery Diabase.*

Some forms of platy diabase appear to be due to a special development of jointing in the diabase. This form was favoured by the natives for making their stone axes, and several small quarries occur close to the road, about half a mile north of the old road terminus. More often they appear to represent altered tuff beds. Rocks of this nature occur at intervals throughout the area, but the outcrops are not readily traced. The most characteristic and tuff like occur on Lick Hole Creek, about a mile above Malcolm's Creek. Here they are somewhat banded, and suggest stratification. The rock is dark green, and of very fine texture in hand specimens, and under the microscope (section 24) shows a very fine textured fragmental structure of minute angular fragments in a matrix which cannot be resolved. Section 23 is a basic platy rock with coarse and fine banding, but is altered, and in parts serpentinized so that its original character is not recognisable, but the probability is that it represents a tuff. The splintery diabase is a fine-grained green variety, which splits readily into long slender splinters, or pencils with angular edges. It is found in contact with massive diabase at the north-western extremity of the small diabase area, a little less than a mile in a straight line south of Fry's.

It can be matched exactly with a similar occurrence at Heathcote south of Photograph Knob, where Professor Skeats regards it as an altered tuff.

B. *Agglomerate.*

A well-marked breccia occurs on the east-west ridge between the Howqua and Fry's, and the Lick Hole Creek. It forms one of the prominent points, and is marked Breccia Knob on the map. This rock is a typical breccia, made up largely of igneous fragments, but contains also some banded chert. Sections of the chert examined suggested strongly altered tuff, and were of coarser texture than the *Protospongia* chert. Under the microscope a thin section of the breccia (Section 14) shows it to be made of fragments so dense as to be almost opague, but small pyroxenes present indicate that the material is igneous and represents rapidly cooled lava. If the eruption were submarine, as it is believed the general evidence indicates, the rapid chilling of parts of the lava would be expected.

C. *Alteration Features of the Diabase.*

(*a*) *The Red Jasper.*

The bright red colour of this rock together, with its hardness and durability make it rather a conspicuous and characteristc rock in the recent river gravels in the diabase region, and also an easily recognizable pebble in some of the Upper Palaeozoic conglomerates.

It occurs in situ in the diabase as apparent inclusions,[1] for which they have have been mistaken, but it is clear in the Howqua, as in the Heathcote region, as shown by Professor Skeats, that it represents one of the phases of metasomatic replacement of the diabase. A good section can be studied in the bed of the Howqua River at low water, about one and a-half miles above Fry's, as shown on the map. The irregular shape is typical of patchy replacement areas, and miscroscopic sections occasionally show relic structures of the original igneous rocks, though in general the action has gone so far that all that is seen is an aggregate of secondary quartz and iron oxide stain.

These jaspers occur at intervals along a definite line, bearing from north-west to south-east, that is, coinciding with the general trend of the diabase.

They vary from small aggregates of jasper patches to larger masses of perhaps 50 to 100 square yards in extent. Associated with the normal red jasper there are often other varieties of quartz varying both in colour and texture, milky quartz and granular quartzitic forms being frequently present.

The linear arrangement of these outcrops suggests the occurrence of a shear or fracture zone along this line, which favoured at recurring intervals the access of silicifying solutions. The jasper which is a definite alteration product of the diabase is distinct in character from the black bedded cherts, which are altered stratified deposits.

(b) *The Siliceous-Carbonate Rocks.*

These rocks form a very striking and characteristic alteration product in the diabase area, and are identical in character with similar rocks occurring in Heathcote. In appearance the rock has a somewhat schistose structure due to fine and contorted banding. (Sec. 51.) It has a prevailing brown colour, with greenish streaks due to a substance allied to selwynite or green chalcedony, which also occurs in lenticles and patches. Numerous sections examined by Professor Skeats from Heathcote indicate that this was originally a diabase or diabase tuff which has suffered alteration in two stages. First it was subjected to a carbonating solution, which produced a mixture of iron, lime and magnesian carbonates, and, later, siliica bearing solutions invaded the rock, replacing in part the original carbonate.

Four separate outcrops of this rock have been noted. One is in the bed of the Howqua, at the pack horse bridge. near Fry's—(specs. 51-54); a second about a mile farther down the river, associated with the smaller diabase area; the third is on the track to Cameron's Creek—(Spec. 44)—about a quarter of a mile south of Lick Hole Creek; and the fourth is about half mile to the south-west of this spot—(Spec. 113). The two lastnamed occurrences are in close proximity to a serpentine outcrop, and the first is on a fracture line leading to another serpentine area. It may be, therefore, that the concentration of carbonates in one place may be casually connected with mineral redistribution, which took place during serpentinization.

C. *The Talc Rocks.*

These rocks vary from massive talc rock and talc schist, undoubtedly altered diabase to talcose sediments, which may be altered tuff beds. The latter will be referred to again, when dealing with the lower Palaeozoic sediments. Talc rock is abundant at the north-western end of the diabase area, in the valley of Stockyard Creek, and its greasy nature adds to the difficulty for horse traffic on the steep graded track to the Howqua from Timbertop

Gap, especially in the present bad state of repair of the road. In general it occurs at intervals along the western margin of the large diabase area, and round the edges of the smaller one. Though sometimes massive it is generally schistose and iron-stained. The crushed margins of the diabase appear to have been most favourable for its development. At Cameron's Creek about a mile and a-half south of Lick Hole Creek, a schistose talc rock with very little iron stain appeared to be slightly auriferous. Some prospectors at work during the writer's examination obtained a fair prospect of very fine gold from a trench entirely in this rock.

(*d*) *Serpentine and Chrysotile.*

Three outcrops of serpentine, all of fairly limited extent, have been noted. The largest occurs on a ridge about half a mile south of Lick Hole Creek, in the track to Cameron's Creek. It is of the usual dark green type, and varies from massive to schistose. Isolated grains of chromite have been detected in it, but no quantity of this mineral has yet been found, nor has any corundum been observed in this district, as in the case of the Dolodrook and Heathcote regions. A thin section shows the rock to be completely serpentinized, and it possesses the platy structure of antigorite, and is, therefore, probably due to the alteration of a pyroxene rock.

The second outcrop is about a mile south-east of Fry's, on the western margin of the diabase; its extent is masked here by much surface soil and hill slip material.

This outcrop is noteworthy, because it contains chrysotile asbestos. The increased demand for asbestos during the war, both locally and abroad, has induced much searching after local supplies, and this occurrence has been taken up by Mr. Fry with a view to opening it up to prove its worth. At the time of my visit only shallow hillside cuts had been made. These revealed thin veins of chrysotile traversing the serpentine along numerous joints and slip planes forming a network which at some of the intersections developed into knots or centres of chrysotile. All the material noted was of a slip fibre type—that is, it consisted of somewhat overlapping fibres lying parallel to the joint and slickenside planes. None of the cross-fibre type was observed. With regard to the origin and development of chrysotile veins in serpentine, the subject has been discussed by Graham in Economic Geology.[9] His inquiry leads him to favour the idea that the agents of change for the Canadian occurrences were magmatic siliceous waters derived from neighbouring granitic intrusions.

Twelvetrees,[10] in describing the asbestos occurrence in serpentine at Anderson's Creek, near Beaconsfield, Tasmania, also postulates a causal connection of the origin of the asbestos with a neighbouring granitic intrusion.

At Heathcote and Howqua the rocks have certainly been invaded by siliceous solutions, and in each case granitic intrusions are present in close proximity. It is reasonable, therefore, to suggest at any rate that the vicinity of an acid magna may have provided conditions which were favourable for the remarkable selective metasomatic and other changes, which were wrought along favourable lines and zones in both of these areas. At Howqua, grano-diorite occurs on the southern slopes of Mount Buller, and a mass of dacite porphyry of related age is actually in contact with the diabase between the Howqua and Timbertop.

(*e*) *Mineralization of the Diabase.*

Another phase in the alteration of the diabase is shown by the siliceous sulphide occurrence at the abandoned gold mine, about a mile south-east of Fry's. The occurrence is an interesting one, and it has been known under different names during its chequered career as a mining venture, but perhaps its best known title is the Great Rand Mine. No accurate survey of this deposit has been made so far as the writer is aware, but like many sulphide occurrences its shape would appear to be irregularly lenticular, consisting of a metasamotic replacement in a fracture zone. The quartz is tough, and very finely granular, and the sulphides are abundantly distributed through it. Iron sulphides, pyrite and pyrrhotite, predominate, but, galena, sphalerite, chalcopyrite and arsenopyrite were noted in small quantity. During my last visit to this region, the mine was being tested by a small syndicate, with the view to determining whether it was possible to treat the ore profitably. The deposit was systematically sampled under the direction of Mr. W. A. T. Davis, of Melbourne, and through the courtesy of Mr. Cottingham, one of the syndicate, I was able to note hurriedly the character of the deposit, as far as the old workings would permit. These reveal a mineralized zone about 300 feet long, in a north and south direction, by nearly 200 feet from east to west.

The mineralization is irregular, and sulphides are found in varying quantities throughout the rock from considerable masses to a mere impregnation. The examination was too short to determine whether any definite system or plan of arrangement for the mineral material could be recognised, but the observations suggested two sets of fracture lines, or planes, one set about east and west, another approximately at right angles. Along the former especially, mineral solutions have been very active, replacing the original rock with sulphides associated with quartz or calcite. Two active processes accompanying the sulphide formation appear to have been silicification and carbonation. Much of the original rock in places appears to be almost completely carbonated, as is shown in a slide (No. 102), from the southern end of the working. From Mr. Cottingham I have since heard that the result of the sampling indicated an average value for the deposit of about 8 dwts. per ton, which they did not regard as sufficeintly encouraging under the circumstances to lead them to undertake further work.

It is interesting to note that if a north-west to south-west line through this mine be produced in either direction, it follows the trend of the diabase and includes other auriferous occurrences at intervals. The old alluvial workings in Stockyard Creek lie at the north-western end. Another abandoned mine occurs to the south-east, on Malcolmn's Creek, while still further in this direction extensive alluvial workings, long since worked out, are found in the upper portion of Lick Hole Creek. Nothing to suggest a continuous line of lode has been noted along this line, but a probable fracture zone is suggested which provided at intervals favourable access to mineralizing solution. This is in conformity with another parallel line to the east previously referred to, along which siliceous replacements have taken place chiefly resulting in the formation of red jasper.

The Cameron's Creek gold occurrences appear to be of the more normal reef quartz type; at any rate, the adit examined in this area revealed a quartz lode with well defined walls, of decomposed diabase. This is on the southerly portion of the smaller diabase outcrop. A section of the igneous rock (No. 50) showed much chloritization, but traces of an original hornblende were recognizable by cleavage lines preserved in iron oxide; triclinic felspar was recognizable, and secondary calcite was moderately abundant.

A brief report on the mine was made by the late James Stirling[11] in 1888, in which he described the Cameron's Creek reef as consisting of quartz segregations in intrusive diorite.

D. *Lower Palaeozoic Sediments.*

These are found enclosing the diabase on all sides, except where later dacite porphyry or Upper Palaeozoic sediments overlie it at the northern extremity. These rocks are mapped as Silurian on the 8 inch Geological Map of Victoria, and until the writer's examination the only fossil recorded from this region was a *Monograptus* obtained by Mr. A. M. Howitt, and indentified by the late Dr. T. S. Hall.

The present field work has brought to light other graptolites, ranging from Lower to Upper Ordovician and *Protospongia* in cherts identical with those of Heathcote now included in the Cambrian, and possibly also radiolaria in the same cherts. The fact that the graptolites are poorly preserved, and separated by large intervening barren areas, makes the working out of the correct stratigraphical succession in this area very difficult. In fact it would be unwise in the present state of our knowledge in this region to attempt to mark boundaries between the different members of the Lower Palaeozoic. We can only note that the succession probably ranges from Cambrian to Silurian, and no unconformability has with certainty yet been recognised in this region.

At Heathcote no certain line of division can be drawn between the lowest beds of the Ordovician and the uppermost of the Cambrian. The Dinesus tribolite beds form a bench marking the Cambrian, but above them there is a great thickness of unfossiliferous sediments which seem to pass comformably into the Ordovician.

In the area above mentioned, and in the Howqua region, it would appear that there has been a continuous sedimentation from Cambrian, through Ordovician, and possibly, too, into Silurian in the last area. The fossil record is, however, unfortunately very imperfect.

(*a*) *Lithological Features of the Sediments and Apparent Relationships.*

There are certain broad lithological distinctions which are apparent, and features also with regard to the general distribution which call for discussion.

First, there is a marked lithological contrast on either side of the main diabase area.

On the western side only Upper Ordovician and, possibly, Silurian graptolites[1] have been noted, and these come from a very restricted area. Slaty rocks often somewhat talcose and chloritic prevail, sandstones and quartzites being subordinate. The rocks are frequently intensely contorted, particularly at the "Governor," and a long line to the north west of this.

The unweathered slates were often black, as at the outcrop below the pack-horse bridge at Fry's. By oxidation and leaching, however, they are often almost white.

They only show slight local chertification, and no *Protospongia* has been noted in these cherts.

On the eastern side, however, the black *Protospongia* cherts are well developed, forming a continuous belt up to half a mile in width, directly in contact with the diabase. These cherts stop suddenly to the east and give place to a dark, micaceous and slightly felspathic sandstone, which appears to be quite conformable and then follows a thick succession of olive green phyllitic slates, alternating with sandstone and quartzite. Traversing these rocks across the strike in a north-easterly direction towards Mount Buller, at about one and a-half miles from the cherts, thin black slate bands begin to occur interbedded with the olive green slates and sandstone. Two of these bands have yielded *Tetragraptus* and *Didymograptus*, thus indicating a Lower Ordovician horizon. Continuing still further to the north-east, and approaching the Mount Buller grano-diorite, these sediments give place to belt of dark cherty slates, and fine grained quartzite, often veined with quartz. Microscopic sections of these rocks indicate contact phenomena attributable to the proximity of the plutonic intrusion. These indurated rocks form a very jagged outcrop, to which the rough outline of Little Buller is due.

Following up the valley of the Howqua, the direction is in general easterly, and, therefore, crosses the strike of the same series of sediments in an oblique direction. The Lower Ordovician strata, yielding *Tetragraptus* and *Didymograptus*, have not been noted, but at a few chains west of Eight Mile Creek, indistinct graptolites were found in black cherts. These were too poorly preserved for certain identification, but they suggested *Diplograptus*

---

[1] The writer has spent days searching along the restricted area where Mr. A. M. Howitt obtained a graptolite, identified by Dr. T. S. Hall as a *Monograptus,* but did not find a single specimen of this genus, though hundreds of specimens of less restricted range were obtained, chiefly *Climacograptus* and *Diplograptus,* with probably *Glossograptus* and other doubtful forms.

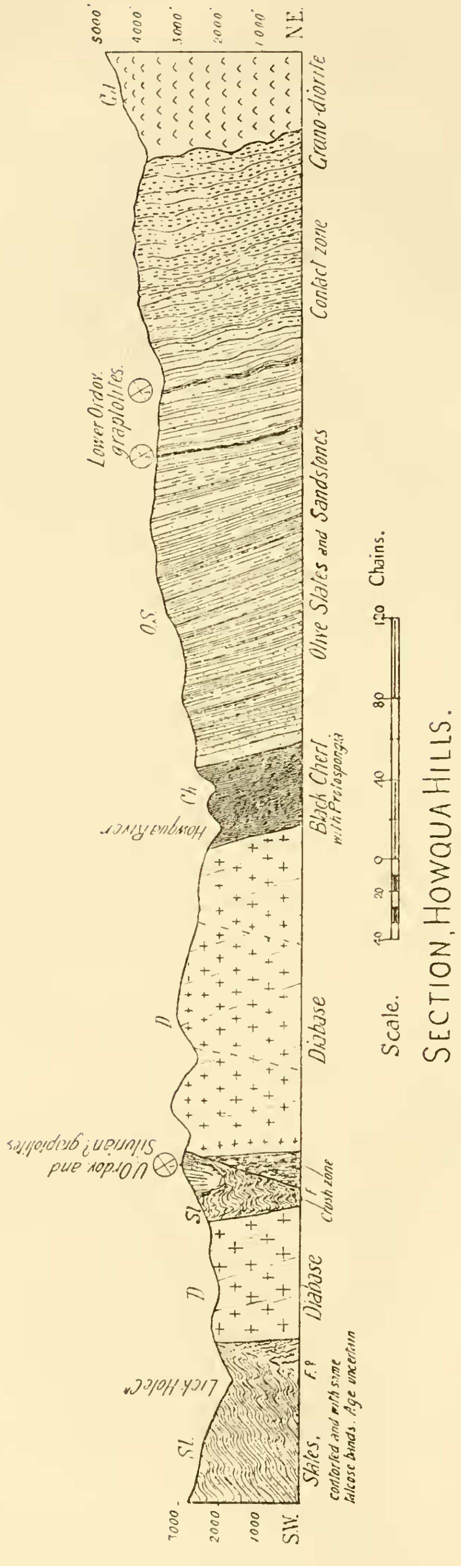

NE.
5000'
4000'
3000'
2000'
1000'
G.d.
Grano-diorite
Contact zone
Lower Ordov. graptolites.
O.S.
Olive Slates and Sandstones
Ch
Black Chert with Protospongia
Howqua River
D
Diabase
U.Ordov. and Silurian? graptolites
Sl.
F
F
Crush zone
D
Diabase
Lick-Hole?
F?
Sl.
Slates, contorted and with some talcose bands. Age uncertain
S.W.
3000
2000
1000
Scale.
40
20
0
40
80
120
Chains.
SECTION, HOWQUA HILLS.

Fig. 3.

and *Climacograptus.* If this is correct, they probably are of Upper Ordovician age. These sporadic occurrences of imperfectly preserved fossils are tantalizing, but they indicate that great caution is necessary in interpreting the stratigraphy of the region.

(*b*) *Structure of the Lower Palaeozoic Area.*

In general, the prevailing dip on the eastern side of the main diabase, as far as observed, appears to be consistently easterly, while on the western side it is to the west. The structure, however, is clearly not that of a simple anticline, for the evidence of the fossils on either side, together with the lithological discordance excludes the possibility of such a view.

A faulted anticline, with the fault approximating to the western margin of the main diabase, is suggested, but this requires an enormous down throw on the western side to bury the great thickness of Lower Palaeozoic sediments represented on the eastern side. The Upper Ordovician, and possibly Silurian fossils on the western side close to the diabase, would appear to demand this view, in the absence of any recognised unconformity to afford any other explanation. The presence of the second diabase occurrence to the west offers certain difficulties, however, in the way of this interpretion.

Another alternative would be to assume that the Upper Ordovician, with possibly Silurian, is but a small fragment that has been nipped in by the intense folding to which the area has been subjected. The fossiliferous area is very restricted, further search may extend it, but the writer has spent much time without success looking for fossils in the surrounding strata. It may, therefore, be that the bulk of the rocks which, so far, have proved unfossilferous, are very much older, and may be Lower Ordovician, or even Cambrian. With the present evidence at hand the matter must be left an open question. (See Fig. 3.)

(*c*) *Phosphate Deposits.*

While searching diligently to obtain graptolites to confirm, if possible, the presence of Silurian, as indicated by a reported *Monograptus* found by Mr. Howitt, Professor Skeats and the writer discovered a phosphatic breccia. This was of considerable interest, because it was the report of phosphatic rock from this district that led to Mr. A. M. Howitt's flying visit. The piece shown to Mr.

Howitt was a loose block, which had been brought to the old mine. As no more could be found in the neighbourhood, it was suggested that it might have come from Mansfield.

The position of the present occurrence is shown on the map. It is only about a mile in a straight line, south-east from Fry's, and less than half a mile south-west from the old mine.

The rock is light-coloured, creamish, earthy fragments predominating, but dark, almost black pieces sometimes somewhat cherty, also occur. Rough stratification is noticeable, and the bed has a defined dip and strike conforming with the enclosing rocks. The outcrop is not continuously exposed at the surface, and has the appearance of being broken and dislocated. The rocks in general in this zone are much disturbed. The phosphatic breccia, however, can be traced at intervals along a distance of about 130 yards, in a north-west to south-east direction.

Wavellite is abundant in thin seams along some of the joint planes, and an analysis of the surface rocks shows that it is an impure aluminous phosphate, containing only about 7% of P_2O_5. This may represent leached material; at any rate, it would be unwise to say that it represents the composition of this rock at a depth. Lithologically, the material does not resemble the Mansfield phosphate rock, which is not a breccia. The organic remains are imperfectly preserved crustaceans of the character of phyllopod-like forms, while those of Mansfield have been referred to as probably Salterella, thus differing also organically. An account of this phosphate deposit has recently been published.[2]

Since *Tetragraptus* has been recorded at Mansfield, it would appear that both Lower and Upper Ordovician graptolite-bearing rocks are closely associated. At the Howqua, the only fossils in the associated beds are graptolites and occasional brachipods, which may be either Upper Ordovician or Silurian, and the phosphate deposits are definitely interbedded with these.

In order to test the relationship of the phosphate deposit to the surrounding sediments, the writer and his father spent a couple of days with pick and shovel putting a trench across the outcrop, the result of which was to prove conclusively that the phosphate breccia is interbedded with the surrounding graptolite-bearing strata. The accompanying section illustrates the relationship.

---

[2] Ernest W. Skeats and E. O. Teale, Aust. Inst. of Mining Engineers, Proc. New Series, No. 32, 1918, pp. 155-165. Fig. 4 is from a block lent by the Aust. Inst. of Mining Engineers.

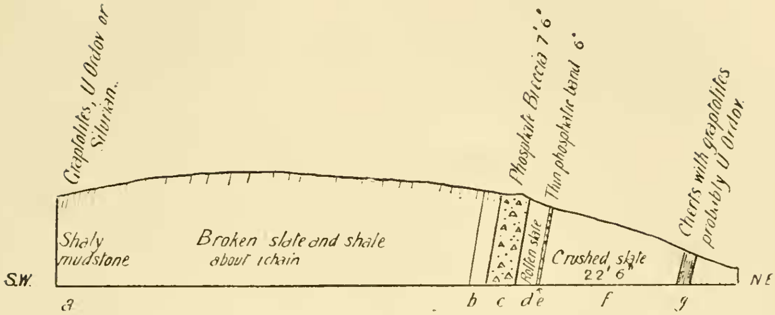

Graptolites, U Ordov or Silurian.
Phosphate Breccia 7' 6"
Thin phosphate band 6"
Cherts with graptolites probably U Ordov.
Shaly mudstone
Broken slate and shale about 1 chain
Rotten slate
Crushed slate 22' 6"
S.W.
N.E.
a
b
c
d
e
f
g

Fig. 4.—Section across outcrop of phosphate breccia.

E. *Concerning the Age of the Diabase and the Cherts.—A Comparative Review.*

These rocks from stratigraphical considerations appear to be the oldest rocks in this region, which necessarily places them low down in the older Palaeozoic series, but on the evidence available in this region alone it would be difficult to assign a definite horizon to them.

The view in this direction, however, is strengthened, and much uncertainty as to age is removed, when a comparative review is made of other closely similar occurrences in the State. Various gaps in the evidence, which make any one area in itself incomplete disappear when all are taken in conjunction. The other areas which call for special consideration in this direction are :—

1. Heathcote.
2. Dolodrook River, near Mount Wellington, Gippsland.

The fossil evidence of the *Dinesus* beds with associated *Protospongia* cherts, at Heathcote, established the age of the rocks as Cambrian.

There would seem to be little doubt that the Howqua rocks are on an extension of the Dolodrook line, where the age is definitely fixed by the tribolite limestone. The absence of this evidence at the Howqua, however, is counterbalanced to some extent by the presence of *Protospongia* cherts and overlying Lower Ordovician rocks, containing such graptolites as *Tetragraptus* and *Didymograptus*. At the Dolodrook, Upper Ordovician rocks come directly in contact with the Cambrian. Again, as an offset against the paucity of direct fossil evidence at the Howqua, we have the very complete lithological resemblances and mineral changes which match the typical Heathcote occurrences. There would seem little doubt, therefore, that the diabases and cherts of the Howqua belong to the Heathcotian series, and must be regarded as Cambrian. Whether also some of the adjoining sediments are to be included in this series must at present be left an open question.

6.—The Upper Palæozoic Rocks.

The present investigation was principally concerned with the relationships of the older rocks, but some of the later geology is not without interest, and as rocks of this age are found in the northern portion of the area under consideration, where they come into contact with the diabase, a little time was devoted to roughly demarking their boundaries and noting their main features. The rocks of this series fall into the following groups :—

A.—Devonian.

1. Dacite, porphyry,
2. Granodiorite.
3. Diorite.

B.—The Lower Carboniferous.

1. Basal conglomerates.
2. Rhyolite.
3. Conglomerates.
4. Sandstones.
5. Purple shales

1. *Dacite Porphyry.*—This rock covers a considerable tract of country between Mount Timbertop and the Howqua, and extends easterly towards the Buller Creek, where it gives place to Lower Palaeozoic strata. It is also found to the north outside the region of this map on the fall towards Merrijig. Rock of this nature is widely distributed in the King River Valley, as indicated by Kitson.[12] In both localities it underlies the basal conglomerates of the Lower Carboniferous beds, in which pebbles of the porphyry are not uncommon. In the Howqua area this feature was noted in the Timbertop conglomerates. Professor Skeats[5] has referred to the King River porphyry as related to the Dacites. In hand specimens the rock has a general dark colour, on account of a dark, fine-grained base. It inclines to red, where oxidized and weathered. Phenocrysts of felspar and quartz are abundant, the former predominating, and show up on the dark base, imparting a typical porphyritic appearance. Garnets are frequently recognizable. Under the microscope in thin sections chemical alteration in all the specimens examined has proceeded too far for satisfactory determination.

The structure is typically porphyritic, the base is fine grained and felstic, often showing flow phenomena. The phenocrysts in order of abundance would appear to be, felspar, ferromagnesian mineral, quartz and occasional garnets. The felspars are more or less decomposed, but in general the twinning and cleavage can be recognised. There appears to be about an equal amount of repeated and untwinned forms, but undoubted orthoclase has not been recognised for the refractive index is invariably higher than that of the canada balsam.

The quartz is often rounded, cracked and embayed. The ferromagnesian minerals have been almost completely chloritized, but their outlines are marked by black outlines due to iron oxides. Biotite is indicated, and hypersthene and hornblende are also suggested. The amount of ferromagnesian mineral indicates a rock related to the Dacites (Slides 29, 30, and 32.)

2. *Granodiorite.*—This rock is very abundant in the boulders of the Howqua, but it is only found in situ within the area mapped in the extreme north-eastern corner on the slopes of Mount Buller. Its intrusive character is shown by the contact alteration of the adjoining Lower Palaeozoic strata. All the sections prepared were from boulders in the Howqua, as these were the freshest specimens obtainable, and their source was known with fair certainty. The prevailing rock has a typical granitic structure, and is of a grey colour, but very fine grained varieties are not uncommon, showing a tendency to porphyritic structure.

It is worth recording that a small splash of molybdenite was noted in one of the boulders.

Hornblende, biotite and triclinic felspar are readily recognizable in hand specimens. In thin sections, felspars appear to be slightly more abundant than quartz. Twinned and untwinned forms are about equal in amount. The repeated twinning is very minute, with occasional fine cross twinning, suggesting anorthoclase.

Biotite and hornblende, both green in colour, are invariably present, but in varying quantities in the different slides. In the basic segregation patches, the hornblende predominates, and the nature of the rock approaches that of a normal diorite. In general the character of the rock compares closely with that of the normal granodiorites of the State, and its association with the rocks of a dacite type is also similar. This intrusion, therefore, is probably to be correlated with the general and extensive one affecting eastern and south-eastern Australia, and regarded as Lower Devonian in age.

3. *Diorite.*—This rock has not been observed in situ yet, but fresh specimens are abundant in the river gravels, and, judging from the most basic segregation patches in the granodiorite, it is most probably that the diorite is magmatically related to the granodiorite, and is no doubt associated with it in its occurrences, The rock in hand specimens is medium grained, crystalline, of dark colour, showng abundant hornblende and felspar. In thin sections the structure is holocrystalline, inclining to panidiomorphic, but the ferromagnesian minerals are imperfect in this direction. The felspars are most abundant and appear to be almost entirely triclinic. Quartz is rare, being present only as odd grains. Ferromagnesian minerals are abundant, but bulk less than the felspars. They consist of typical green hornblende and greenish brown biotite.

B. *Lower Carboniferous.*

The age of these rocks is determined from the evidence of the fish remains found in the Mansfield area, with which these beds can be seen to be continuous. They form part of an extensive series of sediments extending from Mansfield south-easterly into Gippsland.

1. *Basal Conglomerates.*—These are not largely developed within the area mapped, but small remnants are found directly overlying the dacite porphyry on the slopes between Timbertop and the Howqua, and one small outcrop in the track near the top of Timbertop Gap rests in the decomposed diabasic rocks. It contains pebbles both of this rock and of the porphyry. Quartz and quartzitic rocks are perhaps the most abundant generally, but porphyry, red jasper, and diabase can generally be recognised.

2. *Rhyolite.*—This is a well-defined sheet of variable thickness which at Timbertop amounts to about 600 feet. It generally rests on the conglomerate, but occasionally this bed appears to be absent, and it rests directly on the porphyry, as on the spur east of Blackbird Creek. Upon it is found almost invariably either conglomerate or pebbly sandstone.

The rock is distinct from the porphyry. It is more felsitic, with fewer phenocrysts, which are entirely felspar and quartz. Flow structure is generally apparent. The colour is generally red and the rock is decidedly more siliceous than the porphyry.

Thin sections show it to be typical rhyolite, but the specimens examined are more ferruginous than those of Mount Wellington, and the felspar phenocrysts, all orthoclase, are more abundant than